Final Report

PARTICLE-COUNTING SATELLITE OBSERVATIONS MADE IN THE VICINITY OF THE JOHNSTON ISLAND HIGH-ALTITUDE NUCLEAR DETONATIONS OF 1963

Prepared for:

AIR FORCE TECHNICAL APPLICATIONS CENTER/TD-3
WASHINGTON 25, D.C.

CONTRACT AF 49(638)-1164

By: G. L. Johnson R. B. Dyce

STANFORD RESEARCH INSTITUTE

MENLO PARK, CALIFORNIA

FOR ERRATA

AD 410338

THE FOLLOWING PAGES ARE CHANGES

TO BASIC DOCUMENT

410338

DEPARTMENT OF THE AIR FORCE
HEADQUARTERS UNITED STATES AIR FORCE
WASHINGTON 25, D.C.

30 JUL 1963

REPLY TO ATTN OF: AFTAC/TD-3B

SUBJECT: SRI Final Report No. 4081

TO: Defense Documentation Center
Cameron Station
Aloxandria, Va

1. Reference: SRI Final Report No. 4081, Contract AF(638)-1164.

2. The cover page and title page of referenced report should be corrected to read "... High-Altitude Nuclear Detonations of 1962."

3. Request all copies of this report in your possession be corrected accordingly.

Robert S. Brundage

ROBERT S. BRUNDAGE
Colonel, USAF
AF Technical Applications Center
DCS/Plans and Operations

410338

STANFORD RESEARCH INSTITUTE
MENLO PARK, CALIFORNIA

SRI

June 1963

Final Report

PARTICLE-COUNTING SATELLITE OBSERVATIONS MADE IN THE VICINITY OF THE JOHNSTON ISLAND HIGH-ALTITUDE NUCLEAR DETONATIONS OF 1963

Prepared for:

AIR FORCE TECHNICAL APPLICATIONS CENTER/TD-3
WASHINGTON 25, D.C.

CONTRACT AF 49(638)-1164

By: G. L. Johnson R. B. Dyce

SRI Project No. 4081

Approved:

for Joseph Wagner
R. L. LEADABRAND, MANAGER RADIO PHYSICS LABORATORY

for [signature]
D. R. SCHEUCH, DIRECTOR ELECTRONIC AND RADIO SCIENCES DIVISION

Copy No. 16
Series B

CONTENTS

ILLUSTRATIONS

TABLES

PREFACE

The work described in this report has only been possible through the cooperation of Prof. J. A. Van Allen and his group at the State University of Iowa and Dr. G. F. Pieper and group at the Applied Physics Laboratory of the Johns Hopkins University. Their assistance and cooperation is deeply appreciated.

Operation of the field site at Guam has been greatly aided by the friendly cooperation and generous assistance of the personnel at Andersen Air Force Base, Guam.

I INTRODUCTION

Based on experience with artificial radiation belts from the Teak and Orange shots (Johnson and Dyce, 1960) and the Argus shots (Van Allen, et al., 1959)* it was expected that there would be some trapping of electrons in the geomagnetic field following several of the Fish Bowl events. Further, there were two satellites aloft (Injun I and TRAAC) with trapped-particle sensors aboard which, it appeared, could profitably be monitored.

For purposes of locating telemetry reception stations, it was convenient to discuss the trapped electrons in terms of two types of expected behavior: (1) those electrons trapped on the higher field lines and mirroring at sufficient altitude so that they create a shell persisting for days or even years and (2) those electrons continuously supplied by the decaying fission debris (located on very low field lines) that are lost over the South American anomaly and that do not encircle the earth.

Observation of trapped electrons of the first type can be made with a satellite at any convenient longitude provided the satellite crosses the proper magnetic shell. The existing net of telemetry receiving stations appeared to provide fairly good coverage of these persistent electrons. However, the near circular orbits of the Injun I and TRAAC satellites and the offset dipole nature of the earth make it advantageous to sample the radiation belt at a variety of longitudes in order to obtain the maximum coverage with a given satellite in B-L space.

Measurement of electrons of the second type, which do not encircle the earth, requires that the receiving stations be located between the injection longitude and the longitude at which the majority are lost. There was a clear need for a station close to the injection area so that

*References are listed at the end of the text.

measurements could be made before appreciable loss had taken place. To meet this need, a telemetry station was set up at Johnston Island. Hawaii would have been satisfactory, but one of us (R.B.D.) was originally scheduled to have spare time and facilities for equipment operation at Johnston Island.

Simultaneously, a receiving station was located at Guam in order to supplement existing stations with measurements of the persistent radiation belt at higher field strength. (The existing equatorial stations at Quito, Lima, and Salisbury sample at lower field strength.) The addition of another equatorial station also increased the probability of obtaining trapped particle intensities immediately following the shot by increasing the percentage of time a satellite was within range of a receiving station. The Guam site also provided coverage of westward-moving positive particles (some evidence for this following the Teak shot).

Both the Johnston Island and Guam telemetry receiving stations functioned satisfactorily during the Fish Bowl series, gathering a considerable amount of data on the trapped electrons. Meanwhile, it has developed that measurement of the trapped electrons from the Fish Bowl events has involved six or more satellites, various rocket packages, a vast array of telemetry stations, and many different research groups. For instance, 14 different papers on the Star Fish belt appear in the February 1 issue of the Journal of Geophysical Research. The work reported here -- reception of telemetry from TRAAC and Injun I at Johnston Island and Guam -- makes a contribution to the program but is, of course, only a portion of the total effort. Dr. Van Allen's group at State University of Iowa and Dr. Pieper's group at Johns Hopkins Applied Physics Laboratory, respectively, have been in the best position to analyze the data from Star Fish. They designed the satellite, and digital processing centers for the data from the various receiving stations.

In view of the timely and thorough analysis they have given the data, now available in the literature (see References on Star Fish), only a summary of our present knowledge of the Star Fish radiation belt need be presented in this report. In addition, the recent observations of artificial radiation belts associated with some apparent Soviet nuclear tests are summarized, and comparisons are made with the earlier Teak, Orange and Argus artificial belts.

II SATELLITES EMPLOYED

A. Satellites Aloft

Prior to the start of the Fish Bowl test series there were three satellites aloft--Ariel, Injun I, and TRAAC--that carried radiation detectors suitable for detecting nuclear burst electrons. The orbit characteristics of these satellites are summarized in Table I.

Table I

SATELLITE ORBIT CHARACTERISTICS

Satellite	Orbit Inclination to Equator	Altitude of Apogee (km)	Altitude of Perigee (km)
Ariel	54°	1,209	393
Injun I	67°	1,010	890
TRAAC	32°	1,110	951

All three satellites are physically aloft at this time but are electrically unusable. Brief descriptions of those satellites monitored by SRI are presented under B and C below.

B. Injun I Satellite

Injun I satellite contained 14 radiation detectors and a one-axis, flux-gate magnetometer. On command from a ground station, the satellite clock time, the magnetometer reading, and the number of counts accumulated by each detector during its accumulation time were read out digitally each second. (These accumulation times vary with the detector, but they are all less than 1 second and greater than 1/4 second.) The satellite continues to read out the registers each second for 8, 32, or 135 minutes depending on the ground trigger command. In May 1962, operation time was limited to approximately two hours per day total and later limited even more severely because of power considerations. The data processing was seriously complicated by malfunctioning of the satellite-borne synchronization clock, loss of the field-alignment caused by the failure of Injun I to separate from GREB, and irregularity of the frame mate.

Of the various detectors contained in Injun I, the Anton 213 thin-window Geiger counter, capable of detecting electrons of 40-kev energy or greater and protons of 0.5 Mev or greater, was the most sensitive detector of beta decay electrons. It was much more sensitive than any of the detectors in Explorer IV aloft during the ARGUS and HARDTACK tests. However, the Anton 213 was highly directional, being lead-shielded except for an aperture of 0.2 steradian, and, hence, the count rate was modulated over wide limits by the complex tumbling of the satellite giving maxima and minima every few minutes.

A p-n junction detector with an angular field of view of 30° diameter, biased to detect 1 Mev and greater, detected electrons with an efficiency of the order of 1 percent and protons with high efficiency. The p-n junction was highly directional, being shielded by 2 mg cm^{-2} over the most sensitive area and greater than 3 gm cm^{-2} elsewhere. In addition, the satellite contained an omnidirectional Anton 213 Geiger counter encased in a 3.5 gm/cm^2 lead cylinder plus approximately 0.7 gm/cm^2 additional shielding (steel, magnesium, silicon, and glass). This detector (included in the Injun Package as a "background" detector for an electron spectrum experiment also aboard) was approximately a factor of five less sensitive than the shielded Geiger counter carried in Explorer IV.*

The characteristics of the relevant detectors in the Injun satellite are summarized in Table II and discussed in more detail in references.

---

* The shielded counter in Explorer IV had an omnidirectional geometric factor of 0.71 cm^2 for a stopping power at 5 gm/cm^2. The background 213 has an omnidirectional geometric factor of 0.14 cm^2 for a stopping power of 3 gm/cm^2.

Table II

SUMMARY OF THE CHARACTERISTICS OF THE RELEVENT INJUN DETECTORS

Detector	Detectable Particles		Directionality
	Electrons	Protons	
Type 213 Geiger counter	$E \geq 40$ keV	$E \geq 500$ keV	directional
p-n junction detector	$E \geq 1$ MeV	$1.5 \leq E \leq 15$ MeV	directional
Type 302 Geiger counter	$E \geq 6$ MeV	$E \geq 45$ MeV	omnidirectional

C. TRAAC Satellite

The TRAAC satellite was operated by the Applied Physics Laboratory of Johns Hopkins University. Its purposes were certain experiments in control of satellite attitude and studies of radiations in space.

The solar-cell power system of the satellite had been sufficiently degraded by radiation damage from the natural radiation so that by the time of the July 9 explosion, operations had been partially curtailed. Power limitation during the days immediately following the July 9 event frequently required the satellite to be turned off on several orbits before it could be monitored over Johnston or Guam and precluded orientation of the satellite by means of its solenoid, with respect to the earth's magnetic field. Following the July 9 event the new radiation belt accelerated the degradation of the satellite power system, and by day 224 (August 12), attempts to command the satellite were no longer successful.

Despite the curtailment of TRAAC operations from the degraded power supply, considerable valuable telemetry was monitored by the Johnston and Guam stations following the July 9 event. Failure of the satellite during August of course prevented its use during subsequent explosions in October and November 1962.

Of the various radiation detectors contained in the TRAAC satellite (Bostrom et al., 1962) an omnidirectional type 302 Geiger counter, the characteristics of which are summarized in Table III, proved to be the most suitable for the detection of fission electrons.

Table III

SUMMARY OF THE CHARACTERISTICS OF THE OMNIDIRECTIONAL TYPE 302 GEIGER COUNTER IN THE TRAAC SATELLITE

Detector	Detectable Particles		Geometric Factor	Directionality
	Electrons	Protons		
Type 302, Geiger counter	>1.6 Mev	>23 Mev	~ 0.75 cm^2	omnidirectional

III SUMMARY OF DATA AVAILABLE

The Injun I and TRAAC satellite passes monitored successfully by SRI during Fish Bowl are summarized in Table IV and Table V, respectively. In addition, the telemetry for both Injun I and TRAAC received at Johnston Island and Guam immediately following Star Fish is summarized in Figure 1.

Table IV

SUMMARY OF INJUN I SATELLITE PASSES MONITORED SUCCESSFULLY BY SRI DURING FISH BOWL

Date (Z)	Receiving Station	Approx. Time of Start of Pass (Z)	Pass Number
19 May	J.I.	0813	#4495
22 May	Guam	0116:35	4533
	"	2345:09	4546
24 May	"	1107:45	4566
25 May	"	0020:10	4574
	"	1118:30	4580
26 May	J.I.	0807	4592
	Guam	2258:30	4601
27 May	"	1006:30	4607
28 May	"	1021:45	4621
	J.I.	1959:45	4627
	Guam	2332:00	4629
29 May	"	1030:40	4635
30 May	"	0859:35	4648
	"	2211:35	4656
31 May	"	2221:50	4670
1 June	J.I.	0600:30	4674
	Guam	0925:35	4676
	J.I.	1911	#4682

Table IV (Cont'd)

Date (Z)	Receiving Station	Approx. Time of Start of Pass (Z)	Pass Number
1 June	Guam	2240:00	#4684
2 June	Guam	0944:30	4690
	"	2104:35	4697
3 June	"	0812:35	4703
	J.I.	1936	4710
4 June	J.I.	0643	4716
	Guam	0830:25	4717
	J.I.	1952	4724
4 June	Guam	2134:10	4725
5 June	"	0841:45	4731
	"	2153:00	4739
6 June	Guam	2018:10	4752
7 June	"	0722:45	4758
	"	2032:05	4766
8 June	"	0742:10	4772
	"	2047:15	4780
14 June	J.I.	0203	4852
	Guam	0532:20	4854
15 June	J.I.	0402 0410:40	4867
16 June	J.I.	0415:40	4881
	Guam	0607:00	4882
	"	1906:32	4890
17 June	J.I.	0242	4894
	Guam	0427:40	4895
18 June	J.I.	0256:30	4908
	Guam	0444:25	4909
	"	1750:30	4917
19 June	J.I.	0314:30	4922
	Guam	0457:45	4923
	"	1804:45	#4931

Table IV (Cont'd)

Date (Z)	Receiving Station	Approx. Time of Start of Pass (Z)	Pass Number
20 June	Guam	0512:30	#4937
24 June	"	0425:50	4992
28 June	"	0337:00	5047
30 June	"	0215:45	5074
1 July	"	0231:32	5088
2 July	"	0103:20	5101
	J.I.	1223:40	5108
	Guam	1408:20	5109
3 July	"	0114:35	5115
	J.I.	1053:40	5121
	Guam	1423:00	5123
9 July	J.I.	1033:40	5204
	Guam	1402:30	5206
	J.I.	1954:45	5209
10 July	Guam	0112:20	5212
	J.I.	0902:50	5217
	J.I.	1046:40	5218
	Guam	1229:20	5219
	"	1422:55	5220
	J.I.	2006:15	5223
	Guam	2335:50	5225
11 July	J.I.	0918:00	5231
	Guam	2350:10	5239
12 July	J.I.	0930	5245
	Guam	1258:08	5247
	J.I.	2038:20	5251
13 July	Guam	0008:50	5253
	J.I.	0944:30	5259
	Guam	1128:12	5260
14 July	Guam	0023:40	#5267

Table IV (Cont'd)

Date (Z)	Receiving Station	Approx. Time of Start of Pass (Z)	Pass Number
14 July	J.I.	0819	#5272
	Guam	1142:05	5274
	"	2249:20	5280
15 July	J.I.	0833:35	5286
	Guam	1157:00	5288
	J.I.	1931:40	5292
	Guam	2302:59	5294
18 July	J.I.	1837	5333
20 July	"	1903:20	5361
24 July	Guam	1031:45	5412
	J.I.	1809:30	5416
26 July	J.I.	0554:30	5437
26 July	Guam	0917:35	5439
	J.I.	1844	5444
	Guam	2023:45	5445
28 July	"	0758:45	5466
	"	2053:35	5473
30 July	"	0832:25	5494
	"	1940:45	5500
2 Aug.	"	0725:00	5535
	"	1833:25	5541
27 Aug.	J.I.	~1026	5883
28 Aug.	"	1038:40	5897
9 Oct.	"	2345:30	6487
11 Oct.	"	0001:30	6501
13 Oct.	Guam	0214:45	6530
	"	1522:40	6538
14 Oct.	"	0230:40	6544
19 Oct.	"	0156:40	6613
20 Oct.	J.I.	1001:30	#6632

Table IV (Cont'd)

Date (Z)	Receiving Station	Approx. Time of Start of Pass (Z)	Pass Number
20 Oct.	J.I.	1150:30	#6633
	Guam	1335	6634
	J.I.	2108:30	6638
21 Oct.	Guam	0033:50	6640
21 Oct.	J.I.	1014:30	6646
23 Oct.	"	2003:45	6679
24 Oct.	"	2018:45	6693
25 Oct.	"	2034	6707
26 Oct.	Guam	1312:09	6717
	J.I.	1905:30	6720
	J.I.	2046:00	6721
27 Oct.	Guam	0015:20	6723
28 Oct.	J.I.	1011:30	6743
	"	2117:10	6749
29 Oct.	"	0836:30	6756
	"	1942:35	6762
30 Oct.	"	0853:05	6770
	"	1957:35	6776
1 Nov.	Guam	1253:50	6800
1 Nov.	J.I.	1842:10	6803
2 Nov.	Guam	0000	6806
2 Nov.	J.I.	0747:20	6811
3 Nov.	"	1914:05	6831
4 Nov.	Guam	2256:40	6847
5 Nov.	J.I.	0646:10	6852
	"	0836:15	6853
	Guam	1021:45	6854
	J.I.	1751:40	6858
7 Nov.	"	0719:00	6880
	"	1821:20	#6886

Table V

SUMMARY OF TRAAC SATELLITE PASSES MONITORED SUCCESSFULLY
BY SRI DURING FISH BOWL

Date (Z)	Location	Approximate Time of Start of Pass (Z)
19 May	J.I.	0516
	J.I.	0708
23 May	J.I.	1935
	J.I.	2132
	Guam	2315
24 May	"	0313:15
	"	0458:15
	"	0649
	"	2359:50
25 May	"	0344:00
	"	0538:40
	"	2053:00
26 May	"	0429:20
27 May	"	0132:00
	"	0319:50
	"	0512:30
	"	2031:00
	"	2221:45
28 May	"	0209:40
	"	0406:30
	"	0555:50
1 June	J.I.	2032
	Guam	2218:25
	J.I.	2225
2 June	J.I.	0017
	Guam	0017:10
	"	0206:55
2 June	J.I.	0211

Table V (Cont'd)

Date (Z)	Location	Approximate Time of Start of Pass (Z)
2 June	Guam	0355:30
	Guam	1910:00
	J.I.	1922
3 June	Guam	0052:40
	J.I.	0101
	Guam	0247:00
	"	0438:30
20 June	J.I.	0600:50
	Guam	0742:15
	J.I.	~ 0752
	Guam	0930:00
	"	1127:00
	"	1319:00
4 July	J.I.	0100
5 July	Guam	~0137
	J.I.	0143
6 July	Guam	0407:00
	J.I.	0432
	Guam	0600:25
	J.I.	0613
	Guam	0755:00
	J.I.	1003
	Guam	1142:00
	"	1334:35
	"	1533:00
7 July	Guam	0258:00
7 July	Guam	0451:30
	J.I.	0505
	Guam	0645:00
	J.I.	0659

Table V (Cont'd)

Date (Z)	Location	Approximate Time of Start of Pass (Z)
7 July	Guam	0840:00
	"	1034:00
	"	1226
9 July	Guam	0427:00
9 July	J.I.	0436
	Guam	0620:25
	J.I.	0631
	Guam	0814:00
	"	1006:50
11 July	Guam	0015:00
	J.I.	0029
	Guam	2307:00
12 July	J.I.	2016
13 July	J.I.	2056:40
14 July	J.I.	1948:20
	J.I.	2141:30
	Guam	2321:30
	J.I.	2331:00
15 July	J.I.	1840
16 July	"	1925:30
17 July	"	2009
18 July	"	1857

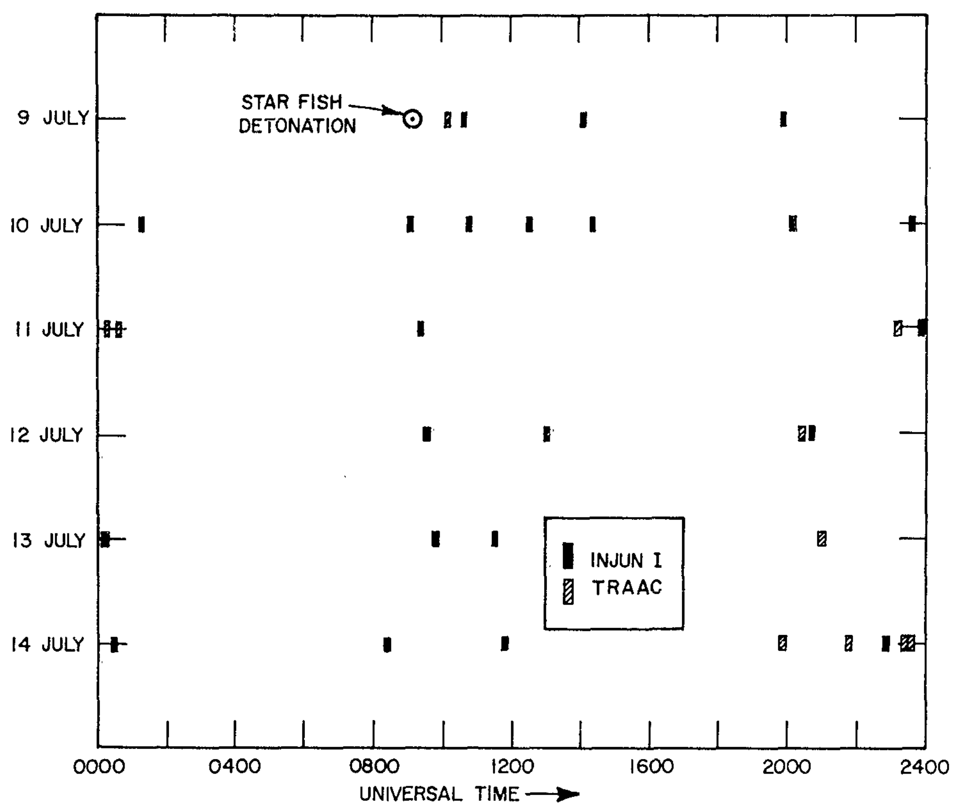

FIG. 1 SUMMARY OF SATELLITE TELEMETRY RECORDED AT JOHNSTON ISLAND AND GUAM FOLLOWING STAR FISH

IV THE MAIN STAR FISH RADIATION BELT

A. Observations Made Immediately Following Detonation

Star Fish, an approximately 1.4-MT yield device, was detonated near Johnston Island at 09h 00m UT on July 9, 1962, at an altitude of 400 km (Dyce and Horowitz, 1963). The first telemetry to be monitored by an SRI station was a pass of the TRAAC satellite over Guam that occurred approximately one hour after the event. At this time a maximum flux in excess of 2×10^7 particles/cm^2 sec was observed at $B = 0.222$, $L = 1.196$ (Pieper et al., 1963). Immediately following telemetry reception at Guam, it should have been possible to receive the satellite telemetry at the Johnston Island and Hawaii stations. However, neither station was able to pick up a signal. It has been suggested that failure to receive the telemetry resulted from blackout effects. However, a 30-Mc riometer located at Oahu indicated the attenuation at H+1 hour was appreciably less than 1 db (Dyce and Horowitz, 1963). A more reasonable explanation would seem to be a malfunction of the satellite resulting from the intense radiation in the burst area.

At approximately 1034 Z (94 minutes after the burst) Injun I satellite was successfully commanded on and monitored by the Johnston Island station. The telemetry showed that there was a belt of trapped electrons from the Star Fish detonation having a maximum intensity at $L = 1.13$ and extending as far as $L = 1.4$ with a maximum omnidirectional intensity of electrons of energy greater than 40 kev of 2×10^7 particles cm $^{-2}$ sec $^{-1}$ (O'Brien et al., 1962).

B. Description of the Main Star Fish Belt

Considerable controversy has existed during recent months with regard to the correct location of the flux contours in B-L space from the Star Fish event. This controversy has centered on the question of what the flux levels are at large distances from the earth, where satellite measurements must be in some cases extrapolated and where the natural radiation background is uncertain.

Van Allen and his group believe the contours shown in Figure 2 (which are essentially the same as those they first published) are a good representation of the belt immediately following detonation. The most intense portion of the belt, in excess of 10^9 particles/cm^{2}sec, occurs at $L \sim 1.2$ on the equator.

Van Allen has extrapolated his intensity contours after subtraction of estimated background to obtain an estimate of the extent of the belt at the equator as shown in Figure 3. The extrapolated contours do not agree with the Telstar observations of Brown and Gabbe (1963) who have made measurements out to $L \sim 2$ using a detector with principal sensitivity to electrons in the energy range 0.25 to 1.0 Mev. Possible explanations of this discrepancy are:

1. A substantial portion of the radiation observed by Telstar at high equatorial L values was present in the natural belts before the burst. (Telstar was launched after Star Fish and, hence, there are no preshot background observations.)

2. The outer fringe of non-fission-like soft electrons observed by Telstar is associated with the nuclear burst in some way. (For example, acceleration of natural electrons, deceleration of debris betas, or preferential deposition of late-time debris betas in this region.)

C. Total Number of Electrons Trapped

Van Allen estimates that the total number of fission decay electrons of energy greater than 40 kev trapped at H + 10 hours was 1.3×10^{25} with an uncertainty of a factor of 2, and that at H + 5.5 months this number had decreased to 2×10^{24}. On the other hand, a recent estimate of the number of Star Fish electrons trapped immediately following the shot, based on the Telstar data is, 6×10^{25} (Hess, 1963). The earlier estimate by Hess (1963) of 2×10^{26} now appears to be in error.

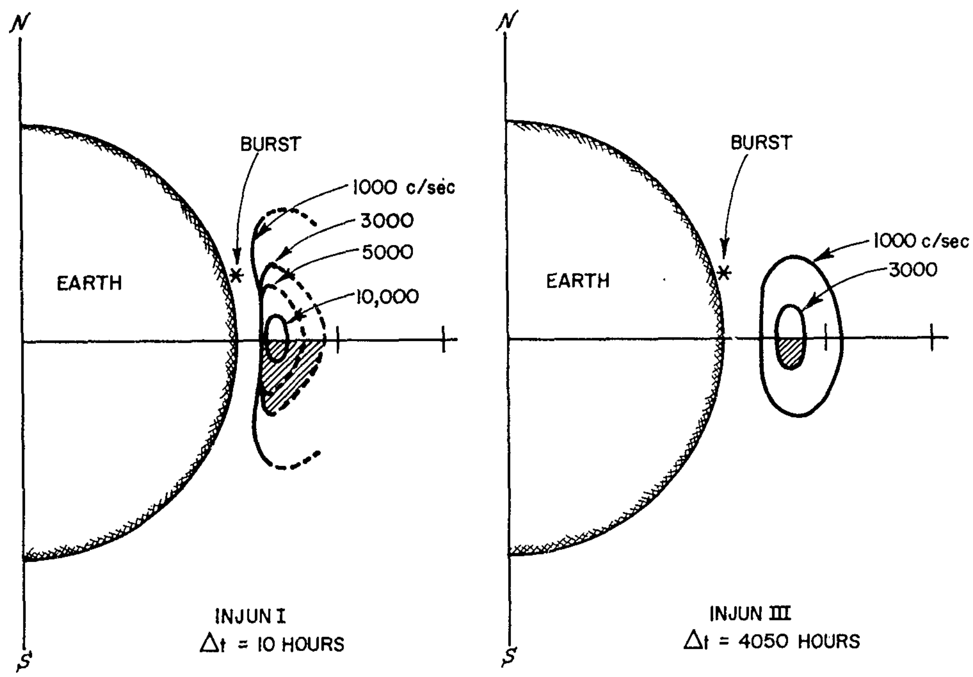

FIG. 2 CONTOURS OF CONSTANT COUNTING-RATE OF THE SPECTROMETER BACKGROUND DETECTOR, Sp B, FOR STAR FISH BELT
The Diagrams are Meridian Cross Section in "Natural" Trapped-Particle Polar Coordinates. Source: (Van Allen, 1963b)

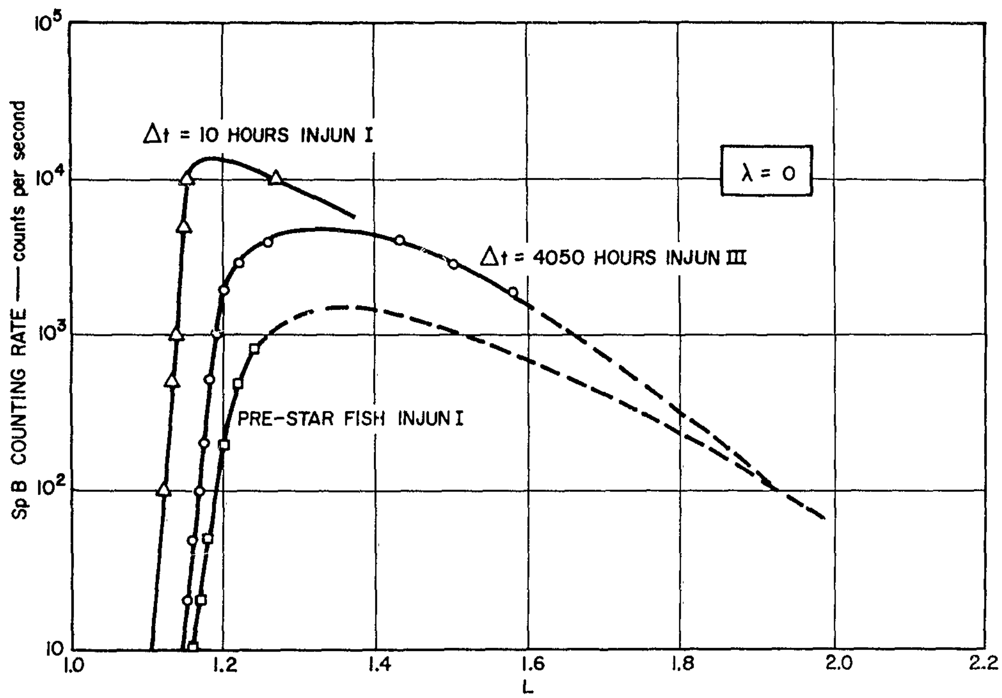

FIG. 3 SPECTROMETER BACKGROUND DETECTOR COUNTING RATE VERSUS THE MC ILWAIN SHELL PARAMETER L AT THE MAGNETIC EQUATOR
Source: (Van Allen, 1963b)

D. Persistence of the Main Star Fish Belt

The decay, over time, of the Star Fish belt is characterized by a rapid decay for the first two weeks, followed by a much slower rate of decay. See Figure 4.

It appears that a useful representation of the time decay at long times (greater than 1,000 hours) is the function $e^{-t/\tau}$ where t is the time elapsed since detonation and τ is a constant now believed to be more or less independent of B for $t > 1{,}000$ hours and mirror heights above 150 km. The independence of τ from B results from the apparent lifetime at any point on the shell being determined by the lifetime at the top of the shell over the equator. At any point down the shell the apparent decay is governed by the decay in the flux diffusing into the sector from the next higher sector on the shell. Thus, the apparent lifetime of the flux at any point on the shell is governed by the atmospheric density over the equator at the crest of the field line. At the Spring meeting of the American Geophysical Union the following values of τ were presented by Van Allen (Van Allen, 1963b):

L	τ
1.15 to 1.25	2.4 months
1.20 to 1.30	2.9 months
1.25 to 1.35	4.2 months

At L values greater than 1.7, the time constant suddenly becomes much shorter, and the trapped particle intensity is subject to large changes associated with magnetic storms. One also begins to see the effect of acceleration processes.

In Figure 2 and 4 the decay of the Star Fish belt during a period of 5.5 months can be seen. It is apparent that the artificial belt has been primarily eaten away from below and the sides, and somewhat from above. The center of the artificial belt, originally at about L = 1.20, has moved out to about L = 1.35.

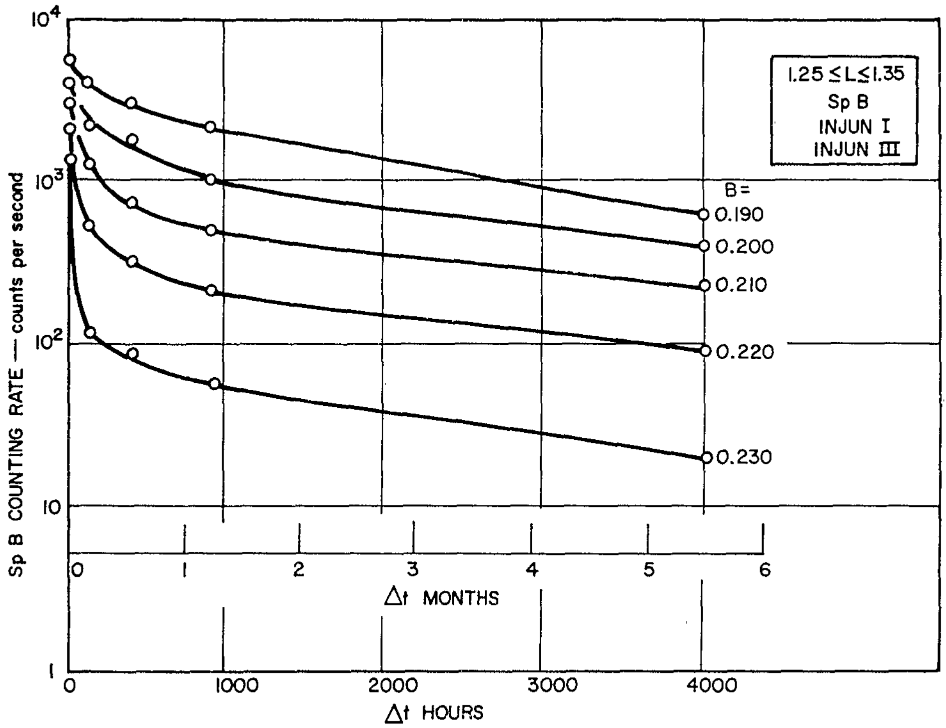

FIG. 4 SPECTROMETER BACKGROUND DETECTOR COUNTING RATE CORRECTED FOR PRE-BURST BACKGROUND VERSUS ELAPSED TIME AFTER DETONATION FOR VARIOUS FIELD STRENGTHS B AND L IN THE RANGE 1.25-1.35
Source: (Van Allen, 1963a)

V THE SECOND STAR FISH RADIATION BELT

A. General Comments

Evidence of the existence of a second radiation belt following the Star Fish event--under the major belt off the equator and blending into it at the equator--comes from the TRAAC and Ariel satellites. Both satellites detected a low-altitude radiation belt at low L values. This second belt was most intense at longitudes between the burst area and the Atlantic anomaly. A similar low-altitude belt was observed following the Teak and Orange shots (Johnson and Dyce, 1960).

B. Location of the Second Radiation Belt in B and L Space

The best information on the location of the second Star Fish radiation belt in B-L space comes from the TRAAC satellite, whose 302 Geiger counter count-rate contours are shown in Figure 5. It can be seen that the peak of the belt occurs at an L value of approximately 1.16 and that there is a monotonic decrease in the count rate with increasing magnetic field strength.* The peak of the low-altitude belt observed by the Ariel satellite (Figure 6) appears to occur at an L value of approximately 1.20. The low-altitude radiation belts observed following the Teak and Orange shots extended out to L values of approximately 1.1.

C. Extent of the Second Radiation Belt in Longitude

Observations of the second radiation belt have been made at various longitudes, indicating that it encircles the earth. However, the most intense portion of the belt is located at longitudes lying between the detonation area and the Atlantic anomaly. This results from the fact that the beta decay electrons that form the second

---

*The coordinates of the burst were L = 1.12 earth radii and B = 0.29 gauss (Van Allen *et al.*, 1963).

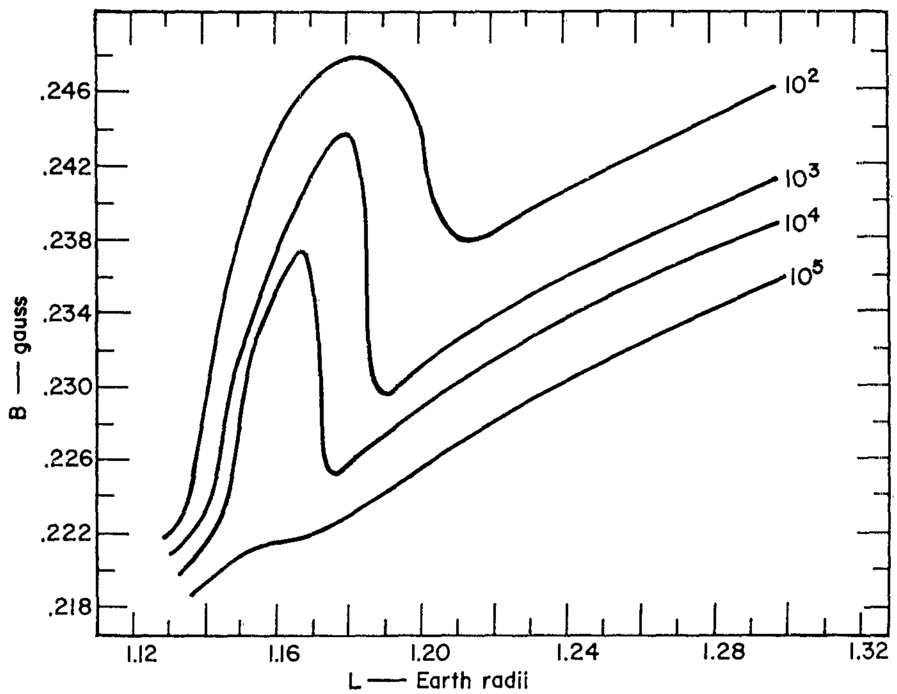

FIG. 5 FLUX CONTOURS IN B-L SPACE FOR THE SECOND STAR FISH RADIATION BELT DETERMINED BY THE TRAAC 302 COUNTER IN THE LONGITUDE REGION 180°E TO 230°E
Contours Give the Omnidirectional Flux of Electrons of Energy Greater than 1.6 mev in Units of cm^{-2} sec^{-1}
Source: (Pieper, 1963a)

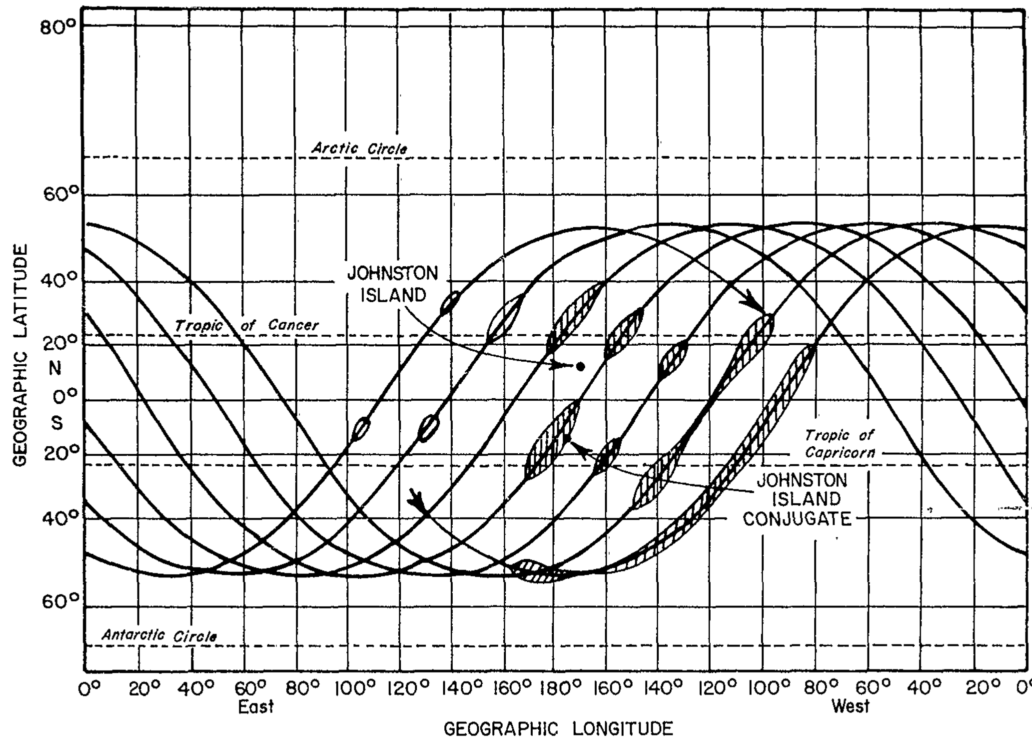

FIG. 6 GEOGRAPHICAL POSITION OF THE LOW-ALTITUDE JOHNSTON ISLAND SHELL ON JULY 9, 1962
Shaded Areas Indicate Positions Where the Geiger Counter was Near Saturation. Unshaded Areas Indicate Relatively Small Intensity Peaks
Source: (Durney, Elliot, Hynds, and Quenby, 1962)

radiation observed on the days following Star Fish are injected at low altitude, and particles mirroring on the L = 1.16 shell at field strengths greater than 0.24 gauss will mirror below 200 km over the Atlantic anomaly, leading to heavy losses. Pieper, using data from Guam, has estimated that 0.5 is the upper limit for the fraction of the second-belt electrons that are able to drift beyond the South American anomaly.

D. Time History of the Second Radiation Belt

Since the electrons in the secondary belt have lifetimes of on the order of an hour, the time dependence of the belt is controlled by the time dependence of the beta decay source, which is known to decay as $t^{-1.2}$ where t is the elapsed time following detonation. Unfortunately because of satellite power considerations, there are very little data available from the satellite during the days following the Star Fish event. The best data on the time variation of the second belt from TRAAC indicates decay by a factor of 5 between July 12 and July 17.

At present, there are, in sufficient published data available from the Ariel satellite to permit the making of a quantitative estimate of the decay law for the second belt. However, Durney et al. expressed the view that the Ariel observations were consistent with the picture of a fission-fed belt, only a vestige of which encircled the earth.

Following shot Teak (1958) the trapped-particle intensity decreased as $t^{-2.3}$ in the vicinity of Johnston Island and as $t^{-1.2}$ observed near Lima, Peru.

E. Origin of the Second Radiation Belt

The source of the second radiation belt is believed to be the continuous feeding of the beta decay electrons from fission fragments that have settled back onto the top of the atmosphere. Immediately following the shot, the primary Star Fish belt formed is sufficiently intense to mask the second belt. However the rapid "eating away" of the bottom of the primary belt soon allows the continuously fed second belt to be observed. While the primary belt, formed, for the most part, in the first hundred seconds following detonation, persists because of low losses, the second persists because of continuous feeding.

F. Intensity of the Second Radiation Belt

As can be seen in Figure 5, the second radiation belt blends into the primary radiation belt over the equator. Where the two belts can be differentiated, the omnidirectional flux of electrons of energy greater than 1.6 Mev exceeded 10^4 cm^{-2} sec^{-1} approximately two days after the shot. The intensity of greater than 0.6 Mev particles observed after the Teak shot over Johnston Island at H + 54 hours was on the order of 8×10^4 cm^{-2} sec^{-1}.

VI COMMENTS ON PRESUMED SOVIET HIGH-ALTITUDE SHOTS OF FALL, 1962

A. General Comments

During the fall of 1962, marked increases in the number of trapped electrons counted were reported by several U.S. satellites--consistent with Soviet high-altitude tests over interior Russia (Wetmore, 1963). Study of these results is particularly important because there is some hope of determining trapping lifetimes as a function of position in space. This knowledge is valuable to an understanding of the natural radiation. Although there is little confirming data in the published literature concerning these explosions, some VLF ionospheric effects have been noted. (Willard and Kenney, 1963)

B. October 22, 1962

An artificial radiation belt commencing on October 22 was first observed by detectors aboard the Alouette satellite several hours after detonation. The observed radiation belt had a sharp inner boundary at small L, a peak intensity of particles of energy greater than 2.8 Mev on the order of 8×10^3 particles/cm^2 sec at approximately $L = 1.88$, and, instead of a sharp boundary at high L, a long tail extending out to an L value of almost 4. Decay by an order of magnitude at the higher L values took about four days (McDiarmid, 1962).

C. October 28, 1962

A radiation belt commencing on October 28 (see Figure 7) displayed a sharp maximum at $L = 1.83 - 1.86$ and a second broad maximum at $L = 2.1$ followed by a long tail extending out to at least $L = 3$. The earliest observations following the shot showed a spectrum similar to fission electrons on the presumed line through the detonation and a much softer spectrum of trapped electrons on the higher field lines. Subsequent passes showed the electron spectrum on the shot line to have been considerably modified from the initial fission-like spectrum.

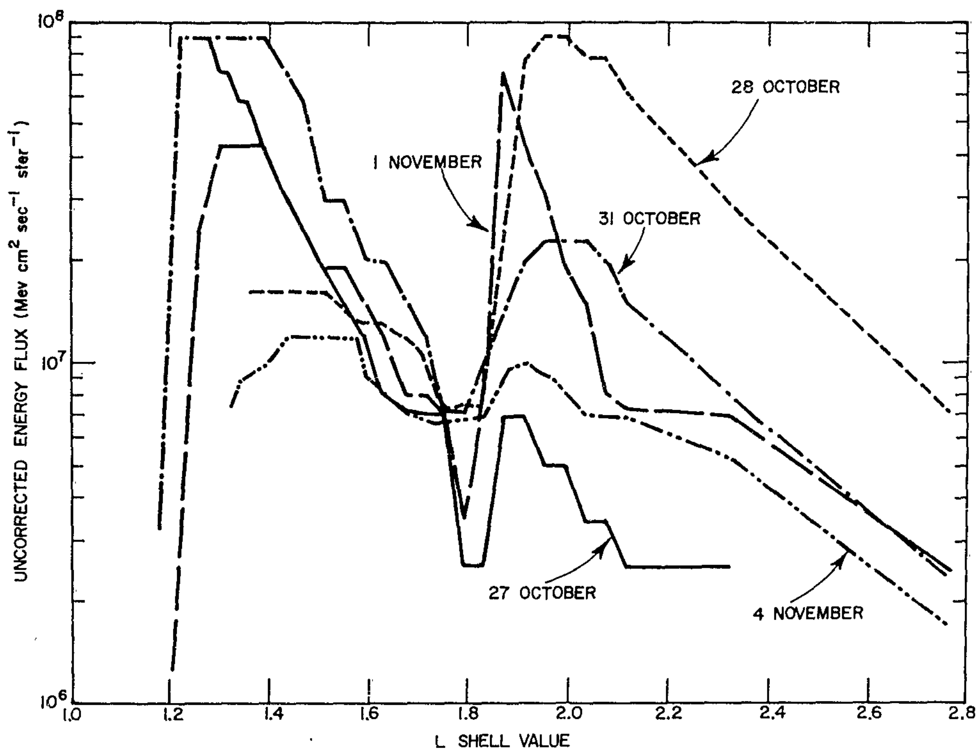

FIG. 7 INTEGRAL ENERGY FLUX (E > 50 kev) B = 0.170–0.205
During Period 27 October-4 November 1962

Measurements of the angular distribution of the radiation trapped from the October 28 shot are available from several packages. They show a peak in the distribution at a pitch angle of about 35° when observed over the equator (Giacconi et al., 1963). Since the angular distribution of the natural radiation reaches a peak at a pitch angle of 90° and falls off slowly, this peak at 35° indicates the shot-associated electrons mirror at low altitudes and were presumably injected there. The calculated field strength of the mirror points of the newly trapped particles shows a tendency to decrease with increasing L, suggesting injection on the higher field lines took place at higher altitudes. During the three days following this shot, the angular distribution shows a return to that of the natural radiation.

D. November 1, 1962

A detonation of November 1, 1962 (several hours before the U.S. explosion of the same date) resulted in a sharply defined radiation belt centered at $L = 1.75 - 1.78$ (Clark and Adams, 1963) and with almost no observable increase in trapped particles on the higher field lines. The observed spectrum was similar to the fission spectrum.

REFERENCES

Argus

Allen, L., Jr., et al., "Project Jason Measurement of Trapped Electrons from a Nuclear Device by Sounding Rockets," J. Geophys. Res., 64, 8, pp. 893-907 (August 1959)

Van Allen, J.A., C.E. McIlwain, and G.H. Ludwig, "Satellite Observations of Electrons Artificially Injected into the Geomagnetic Field," J. Geophys. Res., 64, 8, pp. 877-91 (August 1959)

Welch, J.A., Jr., and W.A. Whitaker, "Theory of Geomagnetically Trapped Electrons from an Artificial Source," J. Geophys. Res., 64, 8, pp. 909-22 (August 1959)

SOVIET TESTS 1962

Clark, B., and D.A. Adams, "Ion Chamber Observations of Trapped Electrons," Trans. Amer. Geophys. Union, 44, 1, p. 77 (P47), (March 1963)

Giacconi, R., F.R. Paolini, and L. Katz, "Measurement of Trapped Particles Injected by Nuclear Detonations," Trans. Amer. Geophys. Union, 44, 1, p. 77(P46), (March 1963)

Katz. L., and D. Smart, "Recent Changes in the Artificial Radiation Belts," Trans. Amer. Geophys. Union, 44, 1, p. 77(P45), (March 1963)

McDiarmid, I.B., et al., "Satellite Observations of Artificial Radiation Zones in October 1962," Trans. Amer. Geophys. Union, 44, 1, p. 77(P44), (March 1963)

Wetmore, W.C., "Radiation Belt Intensity Dispute Grows," Aviation Week & Space Technology, pp. 60-63, February 4, 1963

Willard, H.R., and J.F. Kenney, "Ionospheric Effects of High-Altitude Nuclear Tests," J. Geophys. Res., 68, 7, pp. 2053-56 (April 1, 1963)

Star Fish

Bostrom, C.O., D.J. Williams, and G.F. Pieper, "Charged-Particle Detection Experiments in the TRAAC Satellite (abstract)," J. Geophys. Res., 67, p. 3543 (February 1, 1963)

Brown, W.L., and J.D. Gabbe, "The Electron Distribution in the Earth's Radiation Belts during July 1962 as Measured by Telstar," J. Geophys. Res., 68, 3, pp. 607-18 (February 1, 1963)

Star Fish (cont.)

Durney, A.C., et al., "Satellite Observations of the Energetic Particle Flux Produced by the High-Altitude Nuclear Explosion of July 9, 1962," Nature, 195, 4848, pp. 1245-48 (September 29, 1962)

Hess, W.N., "The Artificial Radiation Belt Made on July 9, 1962," J. Geophys. Res., 68, 3, pp. 667-84 (February 1, 1963)

Motz, H.T., and R.E. Carter, "Artificial Radiation Belt Studies with a Fission Beta-Ray Source," J. Geophys. Res., 68, 3, pp. 657-62 (February 1, 1963)

Mozer, F.S., et al., "Preliminary Analysis of the Fluxes and Spectrums of Trapped Particles after the Nuclear Test of July 9, 1962," J. Geophys. Res., 68, 3, pp. 641-50 (February 1, 1963)

O'Brien, B.J., C.D. Laughlin, J.A. Van Allen, "Geomagnetically Trapped Radiation Produced by a High-Altitude Nuclear Explosion on July 9, 1962," Nature, 195, 4845, pp. 939-43 (September 8, 1962)

Petschek, A.G., "Interpretation of Satellite Detector Counter Rates," J. Geophys. Res., 68, 3, pp. 663-6 (February 1, 1963)

Pieper, G.F., "A Second Radiation Belt from the July 9, 1962, Nuclear Detonation," J. Geophys. Res., 68, 3, pp. 651-6 (February 1, 1963)

Pieper, G.F., D.J. Williams, and L.A. Frank, "Trace Observations of the Artificial Radiation Belt from the July 9, 1962, Nuclear Detonation," J. Geophys. Res., 68, 3, pp. 635-40 (February 1, 1963)

Smith, R.V., and W.L. Imhof, "Satellite Measurements of the Artificial Radiation Belt," J. Geophys. Res., 68, 3, pp. 629-34 (February 1, 1963)

Van Allen, J.A., "Spatial Distribution and Time Decay of the Intensities of Geomagnetically Trapped Electrons from the High Altitude Nuclear Burst of July 1962," State University of Iowa, Publication Research Report No. 63-11, 1963

Van Allen, J.A., L.A. Frank, and B.J. O'Brien, "Satellite Observations of the Artificial Radiation Belt of July 1962," J. Geophys. Res., 68, 3, pp. 619-28 (February 1, 1963)

Walt, M., G.E. Crane, and W.M. MacDonald, "Analysis of Atmospheric Scattering Loss Rates for Geomagnetically Trapped Electrons," Trans. Amer. Geophys. Union, 44, 1, p. 78(P50), (March 1963)

Welch, J.A., Jr., R.L. Kaufmann, and W.N. Hess, "Trapped Electron Time Histories for L = 1.18 to L = 1.30," J. Geophys. Res., 68, 3, pp. 685-700 (February 1, 1963)

White, R.S., et al., "The Artificial Radiation Belts at Low Altitudes," Trans. Amer. Geophys. Union, 44, 1, p. 77(P43), (March 1963)

Synchrotron Radiation

Dyce, R.B., and S. Horowitz, "Measurements of Synchrotron Radiation at Central Pacific Sites," J. Geophys. Res., 68, 3, pp. 713-22 (February 1, 1963)

Kaufmann, R., and T.M. Johnson, "Synchrotron Radiation from the Artificial Radiation Belt," Trans. Amer. Geophys. Union, 44, 1, p. 78 (P53), (March 1963)

Nakada, M.P., "Study of Synchrotron Radiation from the Artificial Radiation Belt," Trans. Amer. Geophys. Union, 44, 1, p. 78(P52), (March 1963)

Ochs, G.R., et al., "Observations of Synchrotron Radio Noise at the Magnetic Equator Following the High-Altitude Nuclear Explosion of July 9, 1962," J. Geophys. Res., 68, 3, pp. 701-12 (February 1, 1963)

Peterson, A.M., and G.L. Hower, "Synchrotron Radiation from High-Energy Electrons," J. Geophys. Res., 68, 3, pp. 723-34 (February 1, 1963)

Teak and Orange

Johnson, G.L., and R.B. Dyce, A Study of Explorer IV Records in the Pacific Area, Stanford Research Institute, Menlo Park, California, Final Report, Contract DA-04-200-ORD-1041, July 1960

STANFORD
RESEARCH
INSTITUTE

MENLO PARK
CALIFORNIA

Regional Offices and Laboratories

Southern California Laboratories
820 Mission Street
South Pasadena, California

Washington Office
808 17th Street, N.W.
Washington 6, D.C.

New York Office
270 Park Avenue, Room 1770
New York 17, New York

Detroit Office
1025 East Maple Road
Birmingham, Michigan

European Office
Pelikanstrasse 37
Zurich 1, Switzerland

Japan Office
911 Iino Building
22, 2-chome, Uchisaiwai-cho, Chiyoda-ku
Tokyo, Japan

Representatives

Honolulu, Hawaii
1125 Ala Moana Blvd.
Honolulu, Hawaii

London, England
19, Upper Brook Street
London, W. 1, England

Milan, Italy
Via Macedonio Melloni, 49
Milano, Italy

Toronto, Ontario, Canada
Room 710, 67 Yonge St.
Toronto, Ontario, Canada